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THE AGRICULTURAL IMPORTANCE OF THE SOIL MESO-FAUNA

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The soil fauna includes the micro-organisms such as bacteria and protozoa and the meso-fauna such organisms as soil arthropods, nematodes and earthworms. One aspect of the agricultural importance of these groups relates to the effect of their activities on soil formation and soil fertility though clearly some groups are also important to agriculture as crop pests, vectors of disease and in other ways.

Because the range in size of members of the meso-fauna is enormous, from larval mites whose size may be somewhere between 5×10^{-7} and 4×10^{-6} ml to earthworms of several ml such as *Lumbricus terrestris*, numbers alone give an inadequate picture of the soil fauna. Biologists have therefore attempted to express the population in other terms such as "biomass".

Different animal populations of equal biomass may not be biologically equivalent and it has been pointed out, for example (Mellanby 1960), that because the metabolic rate of invertebrates is much lower than that of mammals and may be reduced greatly by cold and dryness, the invertebrate soil fauna may not be biologically equivalent weight for weight to mammals. Consequently, statements such as that of Hansen that the weight of earthworms in pasture land may be greater than the weight of stock growing upon it can be misleading if taken for anything more than a picturesque way of translating an unfamiliar concept into familiar terms. Greater importance should be attached to the metabolic rate of different organisms than to their biomass.

However, the activities of the diverse members of the soil fauna differ qualitatively as well as quantitatively, and qualitative differences may outweigh quantitative differences when assessing the importance of particular organisms. The nitrogen-fixing bacteria, for example, may form only a small part of the total bacterial population of the soil and their metabolic rate may be no greater than that of many other soil bacteria, but their importance to agriculture is immense because they perform the unique function of fixing atmospheric nitrogen. Similarly, earthworms are important because they are the principal natural agents in burying dead plant remains, mixing them with the soil and so accelerating decomposition and the release of plant nutrients. The accumulative effect of their activity is so great that their presence or absence can result in the development of two fundamentally different soil types, "mull" and "mor".

Even when different organisms do similar things there may still be important differences. Mellanby (1960) refers to the obvious similarities between surface-casting by earthworms and the formation of molehills and says that "two moles ((weighing 4 ounces each) can bring a greater weight of soil to the surface in 24 hours than can a whole population of earthworms with a total body weight of nearly half a ton". Evans (1948) showed that, in a permanent pasture at Rothamsted, such a population of earthworms brought to the surface 11 tons of soil in a year. Although two moles may bring 70 lb of soil to the surface in 24 hours they would be unlikely to do so every day of the year and so produce 11 tons of molehills! In this respect the analogy recalls the story of the tortoise and the hare. Moreover, molehills can be a nuisance to farmers whereas worm casts are not, unless, as occasionally happens, they are so tall as to resemble molehills and so interfere with harvesting.

The importance of the direct effect of the meso-fauna on the release of plant nutrients from soil organic matter is still undecided. Some of the problems involved can be illustrated by aspects of the nitrogen cycle in soil. Soil micro-organisms excrete ammonia as the nitrogenous waste product when converting soil organic matter into microbial tissue and energy, and this ammonia may then be converted into nitrite and nitrate by further bacterial action. The meso-fauna similarly excrete nitrogen in forms such as ammonia, urea, uric acid and other compounds which are readily converted to available nitrogen. How great is their contribution compared with that of the micro-organisms?

As both groups are poikilotherms their metabolic rate varies similarly with temperature, though the meso-fauna can compensate to some extent for the effects of this by moving from adverse to more favourable conditions, as their well defined seasonal movements show. Although this reduction in metabolic rate in cold weather retards mineralization of nitrogen it may also conserve nitrogen by reducing losses by leaching which would otherwise occur if nitrate was actively produced when its assimilation by plants was retarded by temperature.

Estimates of the weight of bacteria in soil are difficult to make, but Russell (1950) estimated that the top 6 inches of an arable soil at Rothamsted would contain 1,500-3,500 lb fresh weight of bacteria per acre depending on the assumptions made about the size of individual organisms. A comparable estimate for grassland has not been made.

The weight of meso-fauna in most arable soils is relatively small because earthworms, which far outweigh the other groups, are not abundant there. In permanent grassland however their weight is considerable. The often quoted estimate of 1,000 lb per acre is almost certainly an underestimate because the methods used to make it are now known to be inaccurate, and where more accurate methods have been used, e.g. Waters (1955), Raw (1959), earthworm populations of 2,000-3,000 lb per acre have been found.

The intrinsic metabolic rate of many bacteria and earthworms is unknown, but it is unlikely that they are equivalent, weight for weight, though the concept that the metabolic rate of an organism is inversely proportional to its size is applicable to homoiothermic rather than to poikilothermic animals.

Recent laboratory studies by Needham (1957) showed that at 23°C *Lumbricus terrestris* and the smaller *Allolobophora caliginosa*, when feeding on elm leaves, excreted 269 and 88 ug respectively of nitrogen per gram fresh weight per day. Barley (1959) estimated that at 15°C young *A. caliginosa* feeding in a prepared mixture of soil containing 0.20% nitrogen excreted 4.2 ug available nitrogen per gram fresh weight per hour (i.e., about 100 ug daily). If the effect of temperature on excretion is allowed for, these data suggest that earthworm populations such as those described by Raw (1959) for an arable and a grass orchard would excrete about 4 and 6 oz of nitrogen per acre daily when active. If this was sustained for six months of the year the amount of nitrogen excreted would be roughly equal to the amount removed from the soil by an average crop of hay, i.e., 50 lb N per acre.

No strictly comparable estimates for the total amount of nitrogen mineralized by soil bacteria are available because much of it is immediately mobilized. Such estimates as are available involve considerable assumptions, e.g., Jansson (1958) suggests that in an arable soil incubated at 15°C with and without straw about 75 ppm of nitrogen were mineralized in 66 days which corresponds roughly to 40 oz per acre per day.

In this discussion no account has been taken of the type of soil organic matter that earthworms or soil bacteria utilize as food, or the extent to which the activity of one group suppresses or stimulates the activity of the other. Many estimates, especially those relating to micro-organisms, depend on indirect measurements and assumptions, and it is clear that before more reliable estimates of the importance of the meso-fauna can be made and the inter-relationships of the soil fauna understood, many more quantitative data relating to specific activity are needed.

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